Cross-validation with learning-disabled students of the abbreviated Halstead-Reitan Battery for Older Children

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Cross-validation with learning-disabled students of the abbreviated Halstead-Reitan Battery for Older Children

Webb, Paul G., Ph.D.
University of Nevada, Las Vegas, 1989
Cross-validation with Learning Disabled Students of the Abbreviated Halstead-Reitan Battery for Older Children

by

Paul G. Webb

A dissertation submitted in partial fulfillment of the requirements of the degree of

Doctor of Education

in

Special Education

Department of Special Education
University of Nevada, Las Vegas
May, 1989

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The thesis of Paul G. Webb for the degree of Doctor of Education in Special Education is approved.

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Abstract

The present study attempted to cross-validate a screening battery developed by Reitan and Herring (1985) from the Halstead-Reitan Neuropsychological Test Battery for Children. Twenty-eight average (AC) 9-11 year olds were compared to 28 learning disabled (LD) students of similar age and IQ using the Reitan and Herring (1985) screening battery, with the addition of two tactile-perceptual tests—Tactile Finger Recognition (TFR) and Finger-Tip Number Writing Perception (FTNWP). The Screening Index score discriminated significantly (p < .0005) between the LD and AC groups. The mean Screening Index score of the LD group (.23) was over twice as high as the AC group's mean score (.10), with an overall classification rate of 76% (90% for ACs, 62% for LDs). Converted scores (impairment ratings) of the individual measures (7) in the screening battery revealed only three statistically significant differences between the groups (p < .05); however, only 24% or less of the LD subjects earned converted scores within the impaired range on these three measures suggesting little practical diagnostic differentiation between the groups using Selz and Reitan's (1979) impairment levels for the individual measures for LD classification. The tactile-perceptual tests were better discriminators between the
groups with all but one statistical comparison reaching
significance, both for raw and converted score means. Total
Error and Right Hand Error mean scores were the most
discriminating measures, and of the two tactile-perceptual tests,
FTWP was the better discriminator between groups. The Aphasia
Screening Test of the screening battery provided maximum
separation between the groups classifying 95% of the subjects
overall—100% of the ACs and 90% of the LDs.

Results of this study support the use of Reitan and Herring's
(1985) screening battery with 9-11 year olds as a screening
instrument for disabilities from diagnosed or suspected CNS
dysfunction, e.g., learning disability. The screening battery is
clearly enhanced for LD screening with the inclusion of both
tactile-perceptual measures—TFR and FTWP. The AST appears to
offer the greatest diagnostic power for 9-11 year old LDs.
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Introduction

Results of extensive research with the Halstead-Reitan Neuropsychological Test Battery (HNTB) suggest it to be highly effective in differentiating between groups of brain damaged and normal subjects both adults and children (Boll, 1974; Boll & Reitan, 1972; Filskov & Goldstein, 1974; Finlayson, Johnson, & Reitan, 1977; Klonoff & Low, 1974; O'Donnell, Kurtz, & Ramaniah, 1983; Prigatano & Parsons, 1976; Reed, Reitan, & Klove, 1965; Reitan, 1974; Russell, Neuringer, & Goldstein, 1970; Vega & Parsons, 1967). In addition, the older children's version of the HNTB (HNTB-C)—for children 9 to 14 years of age—has been found to discriminate between and among groups of learning disabled, brain damaged, and control subjects with a high rate of success (Selz, 1977; Selz & Reitan, 1979).

Administration of the full Halstead-Reitan battery, however, is very time consuming (6 to 8 hours) for the patient and neuropsychologist, as well as expensive in terms of equipment costs for the neuropsychologist and diagnostic charges for the client (Barrett, Wheatley, & LaPlant, 1982; Wysocki & Sweet, 1985). Because of these constraints, neuropsychologists have attempted to develop abbreviated batteries for screening purposes (Barrett, Wheatley, & LaPlant, 1982; Erickson, Calsyn, & Scheupbach, 1978; Golden, 1976; Wysocki & Sweet, 1985).
Until recently, however, no attempt had been made to shorten the older-children's version of the HNTB (Reitan & Herring, 1985; Tsushima & Towne, 1977), despite the fact that such a shortening would have a number of advantages for the neuropsychologist such as decreased equipment expenses, lower charges to the patient, briefer assessment, etc. Shortening the battery benefits the patient beyond cost and time factors in that abbreviating the battery makes it feasible for use by a broader range of psychologists who have training in neuropsychological principles and assessment and who work with children on a daily basis, e.g., school psychologists. The brevity of a screening battery and its limited equipment costs make it cost and time effective for inclusion in the school psychologist's present armamentarium of assessment instruments. Its brevity also is more likely to retain children's attentiveness and motivation during its administration.

Statement of the Problem

On a daily basis, child neuropsychologists and school psychologists are faced with making complex diagnostic decisions related to the etiology of a referred child's dysfunctional behavior. For these diagnosticians, the question which must be addressed is: "Is the etiology of the child's deviant behavior child or environmentally based?" In such cases, and even in ones
where the adult referral source is unaware of the possibility of
an organic basis, neuropsychological knowledge and assessment
skills can be most helpful (Hynd & Obrzut, 1981).

This is particularly evident in the field of learning
disabilities where the recently agreed-upon definition of LD by
the National Joint Committee for Learning Disabilities includes
the assumption of the etiology as being central nervous system
dysfunction (Hammill, Leish, McNutt, & Larsen, 1981). In the
case of a suspected learning disabled child, the diagnostic team
is expected to rule out confounding factors such as cultural
differences, environmental disadvantage, limited experiences,
sensory handicaps, mental retardation and emotional disturbance.
At the same time the team must identify all of the impaired
intellectual, academic, and "central processing" abilities of the
child (Rourke, 1981). To evaluate these complex factors,
employment of neuropsychological methods is highly beneficial
(Gaddes, 1985; Hynd & Obrzut, 1981; Rourke, 1981). Recent
research in the diagnosis of homogeneous subtypes of learning
disabled students (see Rourke, 1985, for an extensive discussion)
has suggested such an advantage.

Because the Reitan and Herring screening battery (1985) is
new and promising but lacks corroboration, Reitan and Herring
noted that their instrument, with its "weighted percentage

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screening index" of cerebral dysfunction, needs "validat[ion] by additional research and clinical application" (p. 650).

The purpose of this study, then, was to attempt such a validation by assessing the diagnostic accuracy of the "screening index" with a population of learning disabled, 9 to 11 year olds attending public school Resource Room programs. This appeared highly appropriate, given the validity Reitan and Selz (Reitan, 1984, 1985; Selz, 1977; Selz & Reitan, 1979) have brought to the use of the HNTB-C relative to its ability to discriminate between groups of normal and learning disabled children. Using the abbreviated Reitan-Herring screening battery, the present study proposes to determine if a similar differentiation can be made with a high rate of success.
Review of Related Literature

Development of the Battery

Current neuropsychological theory, assessment methods and instruments developed out of the pioneering work of Aleksandr R. Luria and Ward Halstead (Reynolds, 1981). From Luria's work, the Luria-Nebraska Neuropsychological Battery (Golden, Purisch, & Hammeke, 1979) for use with adults was developed. More recently, Golden (1981) developed a Children's Battery to complement the Luria-Nebraska Battery.

The Halstead-Reitan Neuropsychological Test batteries developed from the work of Ward Halstead, and according to Boll (1981) and Reynolds (1981), are more widely used and more extensively researched. The adult battery was formulated out of the experimental work of Halstead which began in 1935 at the University of Chicago (Reitan, 1979). Halstead was interested in studying the psychological effects of brain damage on an individual's adaptive and vocational behaviors. Initially, his research was conducted via naturalistic observations of patients but later incorporated the development of a battery of individual psychological test measures to more systematically evaluate the broad range of brain impairments resulting from disease or damage.

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Ralph Reitan was Dr. Halstead's first graduate student in 1944. After starting his own neuropsychology laboratory at Indiana University Medical Center in 1957, Reitan elaborated, modified, and refined Halstead's clinical procedures to the present state of the three batteries—one for adults, older children (9-14 years) and younger children (5-8 years) (Boll, 1981; Reitan, 1979; Reynolds, 1981; Selz, 1981).

According to Reitan (1979), the test batteries were designed to meet three criteria: (1) To measure a broad range of the major human abilities in order to "permit a psychologically meaningful expression of the effects of brain lesions" (p. 3); (2) to compose the battery with "tests which had previously been indicated by controlled studies to be valid with respect to the effects of cerebral lesions" (p. 3); and (3) to incorporate the "use of the various principles for inference of psychological deficit" (p. 4). Level of performance, pattern of performance, comparison of the left and right side of the body, and pathognomonic "signs" comprise the "various principles of inference." Reitan and most other clinicians in the field of neuropsychological assessment recognize that reliance on only one method of inference, such as level of performance, is inadequate to formulate an acceptable diagnosis and, most importantly, a proper treatment regime (see Filskov & Boll, 1981; Golden,
Osmond, Moses, & Berg, 1981; Reitan & Wolfson, 1985; Rourke, Bakker, Fisk, & Strang, 1985; Rourke, Fisk, & Strang, 1986).

Level of performance reflects the child's obtained score on any individual test in comparison to a norm group. This is the basis of many current psychoeducational measures, including intelligence and achievement tests, where the child's score is compared to those obtained by "average" children of his/her age and/or grade.

Pattern of performance evaluation, on the other hand, involves comparing and contrasting the child's scores across tests to ascertain if strengths and/or weaknesses fall into a consistent pattern, such as, verbal versus nonverbal, motor output versus sensory perceptual, receptive versus expressive language, etc.

The third method of inference, comparison of performance on the left versus the right side of the body, is an extension of the patterns of performance mode. It looks directly at the question of whether the child's impaired functioning can be lateralized (localized) to one hemisphere of the brain or the other, that is, the hemisphere contralateral to the impaired side (hand, foot, eye, etc.), as in the case of a patient with left-sided paralysis or paresis resulting from a right hemisphere lesion.
The final inferential method considered is that of pathognomonic "signs." Pathognomonic "signs" are behaviors or responses which normally are found only in subjects who have brain damage, that is, are not expected for subjects who are not organically impaired. Examples would include a normally achieving 7th grader who is unable to spell the word "CROSS," who names the picture of the fork "a spoon," who cannot reliably locate which finger has been touched with his eyes closed, and/or who draws a grossly distorted likeness of a Greek cross, etc.

**Clinical Value of the Battery**

*With Adults.* A comprehensive review of the clinical usefulness and validity of the Halstead-Reitan Neuropsychological Test Battery (HNTB) is beyond the scope of this dissertation. In addition to Reitan and Wolfson's (1984; 1985) extensive reviews of research on the HNTB, recent reviews by other investigators (Boll, 1981; Golden, Osmond, Moses, & Berg, 1981) have discussed the merits of the HNTB and its clinical value in documenting the adaptive abilities and behavioral impairments mediated by brain damage of various etiologies. Chapter headings in Reitan's (Reitan & Wolfson, 1985) newest book, *The Halstead-Reitan Neuropsychological Test Battery: Theory and Clinical Interpretation,* suggest the variety of brain disturbances with which the HRTNB has been clinically useful: tumors of the brain,
cerebral vascular disease, head injury, Alzheimer's Disease, demyelinating disease, Parkinson's Disease, brain infections, toxic and metabolic brain disorders, aging effects, and epilepsy. Boll (1981) reported that, in multiple independent neuropsychological laboratories around the United States and Canada, the "validity and utility" of the HNTB have been "confirmed."

Neuropsychological evaluation is a complex, inferential process. Therefore, it is important to note that the behavioral sequelae to differing brain disorders can be similar, while on the other hand, two individuals with apparently equivalent brain lesions or injuries can present with differing behavioral adaptations. This is why neuropsychological assessment with the HRNTB measures a broad enough range of abilities to assess accurately the complexity of neuropsychological abilities and disabilities obtained by the patient's hypothesized anomalous brain reorganization, subsequent to disease or injury, and why different tests and subsets of the tests within the battery are more sensitive to specific diseases or disorders of the brain than others (Reitan & Wolfson, 1985; Rourke, Bakker, Fisk, & Strang, 1983; Rourke, Fisk, & Strang, 1986).
With Children. Less research has been initiated with children than with adults; however, studies using the Halstead-Reitan (HNTB-C) and the Reitan-Indiana Neuropsychological Test Battery for Children (RINTBC) batteries have been able to differentiate between normal and brain-damaged children (see Boll, 1981; Boll & Barth, 1981; and Selz, 1981, for extensive reviews). Results of these studies suggest that brain-damaged children perform poorer than their normal peers on a wide array of neuropsychological measures and that the consequences of brain damage to children tend to be different than those to adults. Adults tend to lose previously-obtained skills, whereas children become ineffective in acquiring knowledge and abilities and are particularly impaired in acquiring and using language and symbolic skills (Boll & Barth, 1981; Selz, 1981; Rourke, Bakker, Fisk, & Strang, 1983; Rourke, Fisk & Strang, 1986).

Few studies have investigated the effectiveness of the HNTB-C or RINTBC in differentiating between groups of normal and learning disabled (LD) children. Selz's dissertation (Selz, 1977) and subsequent discussions and analyses of Selz's dissertation data (Selz, 1981; Selz & Reitan, 1979a, 1979b) represent the only research which used the complete HNTB-C and included subjects in the age range of 9 to 14 years.
In the Selz study, 25 normal, 25 brain-damaged, and 25 learning disabled students were subjects. The battery was able to classify correctly 73.3% of the subjects into their respective groups using the "rules" for classifying children developed by Selz. Classification errors tended to be in the direction of identifying subjects as less impaired, with 8 of the 25 LD subjects included within the normal group via the final selection process. Selz (1981) concluded that "these studies do support the beliefs that many learning and behavior problems have a basis in a degree of neuropsychological dysfunction and that neuropsychological testing is a valid tool for discovering the nature of the deficit" (p. 218). As part of the study, Dr. Reitan performed blind subject group membership judgements and correctly classified 80.3% of the subjects.

Analysis by this writer of the available raw score mean data from Selz's (1977) dissertation revealed that, of those tests from the HNTB-C to be used in the present investigation, only the Aphasia Screening Test and Trail Making Test Part A scores significantly differentiated between the control and LD groups. Trail Making Test Part B failed to do so (Control Mean = 33.56 seconds, LD Mean = 64.72 seconds), due to a large standard deviation (53.08 seconds) in times for LD subjects. For the remainder of the measures, mean score differences were in the
expected direction of greater impairment for the LD group. Selz did not investigate differences between the groups on the Name Writing item of the Lateral Dominance Examination.

Reitan and Boll (1973) studied the neuropsychological performance of four groups of 5-8 year olds on the young children's version of the Halstead-Reitan battery. The groups included 25 control subjects (no documented or suspected brain impairment), 25 with minimal brain dysfunction (MBD)—academic deficiency group, 19 minimal brain dysfunction (MBD)—behavior problem group, and 25 brain-damaged subjects. In this study, MBD was defined similar to present Federal LD guidelines—Public Law 94-142 (PL 94-142), Education for All Handicapped Children's Act of 1975. Like the Selz (1977) study, MBD subjects scored more impaired than controls, but not as impaired as the brain-damaged subjects. For the majority of measures, MBD subjects scored equivalently to controls in a level of performance (group mean difference) analysis; however, the academic deficiency MBD group made significantly more errors than controls on the Finger-tip Symbol Writing Recognition Test for the Left Hand. Grip Strength, Finger-tip Symbol Writing (right hand), and Tactile Finger Recognition (both hands) scores did not produce significant differences between groups.
Klonoff and Low (1974) investigated the differences in performance between normals and children with suspected or documented degrees of cerebral dysfunction (Acute, Chronic, Minimal Cerebral Dysfunction [MCD]). In comparison to their age- and sex-matched peers on the Trail Making Test and Finger Tapping Test, the older MCD group was significantly slower, a finding which Klonoff and Low felt demonstrated the validity of their full battery in discriminating between controls and various impaired groups.

Grippaldi (1977) compared the performance of 100 8-12 year old normals to 10 neurologically impaired (NI) and 10 emotionally disturbed (ED) subjects. Characteristics of the students who composed the NI group were not delineated and the only additional descriptor used was "brain-damaged." Measures from the HNTB-C employed by Grippaldi were the Tactual Performance Test, the Trail Making Test and the Finger Tapping Test. A name writing test was included but was scored differently than in the "Rules" set forth by Selz (1977) and Selz and Reitan (1979). While the normal subjects performed "superior" to the NI group on all 14 measures, only four of the differences were significant beyond the .05 level. The NI group compared to the normals: 1) was significantly slower (31.71 versus 26.60 seconds) with their nondominant hand on the Finger Tapping Test; 2) made
significantly more errors on Trails A and B; 3) scored significantly less adequately on the Handwriting test with their dominant hand; and 4) scored differently between hands when right-left hand performance was compared.

Clinical Value of the Individual Measures of the Screening Battery with Children

Trail Making Test. In 1955 Reitan developed a shortened version of the Trail Making Test (TMT) for use with children. Davids, Goldenberg, and Laufer (1957) published the first study with children employing the shortened version. They were able to show, as many studies of adults have shown, that brain-damaged children also perform slower than their normal peers on the TMT.

Reitan (1971) validated Davids, Goldenberg, and Laufer's (1957) results with children 9-14 years old. He found brain-damaged children to be significantly slower on the TMT than their age-, race-, and sex-matched normal controls.

Rourke and Finlayson (1975) compared neuropsychological profiles of LD subjects grouped by their patterns of performance on the two parts of the TMT (A < B, B < A, A = B). The A < B and B < A LD groups presented neuropsychological test profiles similar to those found in adults with deficient right and left cerebral hemisphere functioning, respectively.
McManis, Figley, Richert, and Fabre (1978) included the TMT in their test battery to assess differences in skills of 12 adequate and 12 retarded readers, 8 to 12 years old. No mention was made in their article that the retarded readers, who were at least one year below grade level in reading on the WRAT or PIAT, were learning disabled. The WISC-R pattern for their reading disabled group was similar to Bannatyne's subtype with poor sequencing skills (low on Digit Span, Arithmetic, and Coding, VIQ < PIQ) (Bannatyne, 1974). They found that the reading disabled group earned significantly slower mean times on Part B and the combined A + B times. Part A times were slower, but not significantly so.

Del Dotto and Rourke (1985) reported results of research with subgroups of left and right handed learning disabled children 9-14 years old (N = 322, WISC-R FSIQ 85-115). Of the seven subtypes identified in their sample, five were at least one standard deviation below age expectancy on Part B of the Trail Making Test.

Joschko and Rourke (1985) investigated the neuropsychological profiles of subtypes of children with the "ACID" pattern on the WISC-R (low on Arithmetic, Coding, Information, Digit Span). The Older Subtype 1 (similar to Younger Subtype 4) performed poorly on both Trails A and B.
Mittlemeier, Rossi, and Berman (1988) found that, even with first and second graders (ages 6-8), the Trail Making Test was able to correctly identify 78% of the "Normal" subjects from the "Slow Learners" group. The Normal group completed both parts of the test significantly faster than the Slow Learners.

**Finger Tapping Test.** When comparing the abilities of 9-14 year old brain-damaged and normals on the HNTB-C, Reed, Reitan, and Klove (1965) found the Finger Tapping Test—Dominant Hand and Nondominant Hand—to significantly differentiate between the groups. Boll and Reitan (1972) also found that poorer finger tapping speed distinguished between 9-14 year old brain-damaged and normal children. Klonoff and Low (1974) found similar results for their Minimal Cerebral Dysfunction versus control groups, as did Grippaldi (1977) between his Neurologically Impaired and normal groups for nondominant hand tapping speed. Del Dotto and Rourke (1985) reported that, for five of their seven LD subtypes, nondominant hand finger tapping speed fell within the impaired range.

**Grip Strength.** Boll and Reitan (1972) found significant differences in grip strength between the 9-14 year old brain-damaged and control subjects in their study. Tsushima and Towne (1977) found 6-8 year old children with "questionable brain disorders" to be significantly weaker in the nondominant hand.
than their normal controls. Reitan (1985) was also able to differentiate significantly between his groups of normal and brain-damaged subjects on the Grip Strength Test—difference between hands score.

This test has not been used widely in neuropsychological studies of LD students. Where it has been utilized (Selz, 1977), minimal differentiations between groups of normals and LDs have been noted. Thus, LDs were not significantly weak in Grip Strength in Joschko and Rourke's (1985) study.

**Name Writing Speed.** While many studies have included the Lateral Dominance Examination as one of their measures for comparison, only two have specifically reported data regarding name writing. Grippaldi (1977) did not score name writing for speed; rather, he scored for quality and found the Neurologically Impaired (NI) group to perform poorer than controls both in writing with the dominant hand and in difference between hands ratings. Reitan (1985) found that name writing speed with the dominant hand and differences in time between hands significantly differentiated between normal and brain-damaged 9-14 year olds.

**Aphasia Screening Test.** Selz (1977) and Reitan (1985) have found the Aphasia Screening Test (AST) items to differentiate between normals and children with cerebral dysfunction. In her dissertation, Selz (1977) found the 9-14 year old controls to
produce a mean of .76 aphasic errors, whereas the LD group produced 5.72 average errors. Using a score of two or more aphasic errors on the AST as indicating brain impairment, 92% of the controls and 76% of the LDs were correctly classified. For the constructional dyspraxia items (copying shapes and objects), 8% of the controls and 32% of the LDs produced such errors.

Wolfson and Reitan (1988) found with 6-8 year olds that the 26 brain-damaged and 26 control children in their study were "strikingly different" on mean scores of the Aphasia Screening Test and the distributions had only a "19% overlap".

Tactile-Perceptual Measures. Tactile-perceptual measures used in this study included the Tactile Finger Recognition (TFR) and Finger-tip Number Writing Perception (FTNWP) tests. These tests were included to enhance differentiation between LDs and controls, to add additional lateralizing measures, and to assess tactile input abilities which have been found to be impaired in many LD students (Gaddes, 1985; Reitan, 1984; Rourke, 1985). In studying normal 10 year olds, Reed (1967) found that students with a lateralized difference in tactile finger recognition, in which they made significantly more errors with their right than left hand, showed a 1.4 Grade Equivalent (G.E.) delay in reading when compared to their normally perceiving peers.
Boll and Reitan (1972) investigated the ability of brain-damaged versus control subjects on these two measures (TFR and FTNWP) of tactile perception, as well as on other neuropsychological tests. The brain-damaged group displayed significantly more imperception on the TFR and FTNWP than did their matched 10-14 year-old normal peers.

Finlayson and Reitan (1976) evaluated the "relationship between tactile-perceptual functioning and levels of cognitive, intellectual, and reading ability in younger and older normally-functioning children" (p. 442). The older group was composed of children 12 to 14 years of age and the younger, 6 to 8 years of age. For each age level, upper and lower quartile groups were derived based on the children's performance on the tactile-perceptual tests used (tactile imperception, tactile finger recognition, finger-tip number-writing perception, and tactile form recognition). Scores of these "good" and "poor" groups on the other measures in the study then were compared. It was found that the older group with "good" tactile-perceptual skills earned significantly higher scores than did the "poor" group on measures of cognitive ability (Category Test), reading achievement (Wide Range Achievement Test), and WISC Verbal and Full Scale IQ. The younger "good" group performed significantly better than the "poor" group on the Verbal and Full Scale IQ of
Boll, Richards, and Berent (1978) investigated the relationship of tactile perception and academic achievement for normal and brain-damaged 9-14 year olds. They found that the summed errors on the three tactile-perceptual measures (TFR, FTNWP, and Tactile Form Recognition) predicted relative academic achievement levels for both the brain-damaged and normal students. Those students with significant tactile imperception, whether brain-damaged or normal, scored significantly lower than their adequately perceiving peers on all four subtests of the Peabody Individual Achievement Test. In addition, brain-damaged subjects made significantly more perceptual errors than did control subjects.

Boll, Berent, and Richards (1977) administered a full neuropsychological battery to 50 normal and 42 brain-impaired (epileptic) subjects 9-15 years old. Brain-damaged subjects demonstrated significantly more impairment than did controls on nine of the 10 comparisons; however, when each group was subdivided into a Good Tactile-Perceptual and a Poor Tactile-Perceptual subgroup, the Good Tactile-Perceptual subjects, whether from the brain-damaged or normal group, outperformed the Poor Tactile-Perceptual subjects "on every test of the battery." The researchers indicated that "the development
of tactile-perceptual ability...appears to be a powerful factor with respect to its association with a variety of higher level cognitive functions" (p. 539). Reitan (1984) indicated similar conclusions for children.

In both the Joschko and Rourke (1985) and Del Dotto and Rourke (1985) studies, at least one subtype of older LD students displayed significant impairment on the TFR or FTNWP tests. Performance on FTNWP appeared to be more frequently impaired than finger localization.

**Age Effects for Children on the HNTB-C**

Most studies reviewed in this section, whether they solely investigated age-related changes in performance on the older children's version of the Halstead Neuropsychological Test Battery, or were ambiguous on relative age comparisons, included the age performance question as one of the explored factors. These studies strongly suggest that some type of age improvement measure is warranted in this type of study.

In 1971, Reitan compared the Trail Making Test (TMT) times of 9-14 year old boys and girls who were brain-damaged (N = 35) or normal (N = 98). In looking at age related changes in TMT performance, he found that both boys and girls took significantly less time "as they grow older," that is, at each one year increment for both boys and girls, TMT times decreased somewhat,
with the 14 year olds taking markedly less time than 9 year olds.

In testing 200 normal children between the ages of 9 through 14 years, Klonoff (1971) found age related differences in mean scores on many of the variables included in his study. Scores on the Finger Tapping test increased (Age 9, 33.9 taps; age 14/15, 46.32 taps), while time taken decreased on the Trail Making Test-Part A (9 years, 25.09 seconds; 14/15 years, 14.58 seconds) and Part B (9 years, 54.94 seconds; 14/15 years, 31.58 seconds). Because these changes across age were not investigated directly, no statistical analyses were conducted to determine if the increases in motor speed were significant.

Spreen and Gaddes (1969) and Knights and Norwood (1971, 1980), using their neuropsychological test batteries, directly assessed the effect of age on the functioning of children. Their normative data are broken down into yearly increments for each test to account for what they believe are meaningful changes with increasing age.

In other studies Grippaldi (1977) found that the normal group significantly improved with increasing age for both hands on the Finger Tapping Test and both parts of the Trail Making Test. Hernandez (1977) found significant age related improvements in scores between kindergarteners and 2nd graders on measures in the Halstead-Reitan battery. On the Aphasia
Screening Test, for example, she observed differences at the p<.00001 level on the Copying, Reading, Left-Right Confusion, and Calculation items.

Klesges (1983), in investigating the effects of age on neuropsychological test performance of 9-14 year olds on the HNTB-C, found that age was significantly correlated with performance on the Trail Making Test (Parts A and B), Aphasia Screening Test, and Finger Tapping Test (Dominant and Nondominant hands) with the motor speed scores on the Trail Making and Finger Tapping tests most significantly related.

Fischer, Dean, Rattan, and Nickell (1986) collected neuropsychological test data using the HNTB over 16 years on children 9 to 14 years of age who were diagnosed as learning disabled. Their results were "quite similar to those reported for the LD sample of the Selz-Reitan study" (p. 115). Fischer et al. (1986) cautioned, however, that "reference information pooled without regard for age and gender might lack the specificity necessary to make clinical decisions concerning the children" (p. 118).

In summary, except for the Grip Strength test, all of the measures of the Reitan-Herring (1985) Screening Battery, as well as the two tactile perceptual measures added by this writer, have shown differential results for normal children versus learning
Research on Brief Neuropsychological Batteries

Adult Batteries. To date, most attempts to develop a shortened neuropsychological battery have been with adults. Tests included in each of the batteries were diverse; however, some of the tests were similar across batteries (Trail Making Test, Aphasia Screening Test). All of the batteries were developed as a quick method of assessing the presence or absence of possible brain damage; none, however, has yet replaced the full Halstead-Reitan battery. Consensus of the researchers' complaints about using the complete Halstead-Reitan battery centered around the issues of: lengthy time of administration and interpretation; excessive expense to the client; expensive equipment costs; and extensive training required of the clinician.

Wysocki and Sweet (1985) succinctly delineated the "essential" criteria for the development of a "truly useful [neuropsychological] screening device" when they noted that: First, the choice of tests was empirical in that all of the tests chosen have been used extensively in previous neuropsychological research and have been shown to be effective in identifying individuals with cerebral dysfunction. Second, all of the tests are brief,
easily administered, objectively scored, commonly used in clinical settings, and very portable. Third, tests were chosen that conceptually represent a broad range of cortical functions, including both left and right hemisphere activities. Finally, the battery includes measures for most major neuropsychological skills, including tests for auditory, tactile, visual, spatial, verbal, basic motor, and memory skills. (p. 40)

In his 1976 study, and using an abbreviated battery, Golden tested 30 normal and 91 brain-damaged subjects between the ages of 15 and 75, all of whom were patients referred to clinics for neuropsychological evaluation. The "abbreviated" battery consisted of the Aphasia Screening Test, Speech Sounds Perception Test, Rhythm Test, Trail Making Test (Parts A and B), Stroop Color and Word Test (all sections), and the Block Design, Similarities, Digit Symbol, and Object Assembly subtests of the WAIS.

All of the subjects were administered the full HNTB, as well as the other tests (Stroop, WAIS). Patients initially were diagnosed according to the results of scores from the full battery and then effectiveness of the abbreviated battery was measured against results of the complete assessment. Using discriminant analysis, Golden concluded "the abbreviated battery
is capable of diagnosing brain damage equally as well as the full battery 93% of the time" (p. 821).

Golden cautioned that the abbreviated "battery is only useful to answer 'yes' and 'no' to the question of organicity" (p. 825). He noted that an abbreviated battery would be "most useful for those organizations [school districts] and individuals with limited time [school psychologists] or money who cannot use the full battery and yet are likely to see cases suggestive of organic involvement [learning disabilities]" (p. 825). He suggested that the Sensory-Perceptual Examination of the full battery, among other tests, might be included to supplement the shortened battery. Tests in Golden's abbreviated battery were chosen if they took less than 10 minutes to administer, were independently capable of diagnosing brain damage "at least 70% of the time," were scorable in a "reasonably objective fashion" and required a "minimum of equipment" (p. 822).

Erickson, Calysn, and Scheupbach (1978) obtained a correct classification rate of over 76% in their use of a "short form of the Reitan" battery with 75 adults. A priori, they chose the Trail Making Test (parts A and B), the Aphasia Screening Test, Block Design and Digit Symbol from the WAIS, and age as "predictors...on the basis of ease and speed of administration, general clinical value, and promise as determined by relevant
previous publications" (p. 923). Patients' files were analyzed for accuracy of the predictors in correctly diagnosing the patient as having signs of brain damage or not. Discriminant analysis was used and only 13.33% of the cases were misclassified.

Erickson et al. (1978) felt that the tests included in their abbreviated battery could provide data regarding the possible localization and laterality of damage. Golden (1976), on the other hand, noted that his abbreviated battery "is not capable of making the statements about laterality or process that the full battery is able to make" (p. 825). However, Golden did suggest that "supplemented by other widely available tests, [the abbreviated battery] can be used to identify more closely the nature of the [client's] dysfunction" (p. 825).

Barrett, Wheatley, and LaPlant (1982) administered the following tests to 150 adult patients (50 No Brain Damage [NBD], 51 Suspected Brain Damage [SBD], 49 Definite Brain Damage [DBD]): Shipley-Hartford Scale; Wechsler Memory Scale-Revised; Name Writing Test; Reitan-Indiana Aphasia and Sensory-Perceptual Exams; Constructional Dyspraxia Exam; Trail Making Test; Finger Tapping Test; and MMPI. While the shortened battery was briefer than the full Halstead-Reitan, it took longer to administer than did the other batteries discussed earlier. This battery lasted
about 2 hours. The discriminant predictions yielded a correct classification rate of 95% overall for the first subgroup of the total sample and 72.9% for the validation subsample, producing "a respectable job in statistically distinguishing neuropsychiatric referrals with NBD from those with SBD or DBD" (p. 377).

Barrett et al. (1982) indicated that, for their adult patients (mean age less than 40), the "best discriminators were measures of...pathognomonic signs (e.g., aphasia rating), and right-left differences (e.g., tactile suppressions)" (p. 377), especially when discriminating between the two brain damaged groups. Analysis of the data suggested that using the "multiple methods of inference" (p. 377) approach (level of performance, right-left differences, pathognomonic signs, pattern analysis) was the valid neuropsychological approach to follow; that is, no one inferential method alone predicted brain dysfunction in all subjects.

Wysocki and Sweet (1985) administered their neuropsychological screening battery to 75 hospitalized patients (25 brain-damaged, 25 schizophrenics, and 25 normal medical controls) whose diagnoses had already been made medically. The battery consisted of: Finger Tapping (both hands); Wechsler Memory Scale; Trail Making Test (parts A and B); Digit Symbol subtest of the WAIS; Stroop Color and Word Test; Pathognomonic

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Scale of the Luria-Nebraska and the Spatial Relations (Greek Cross) component of the Aphasia Screening Battery. These specific tests were included in the battery because they met the criteria set forth above (p. 25) after reviewing the literature on screening batteries.

Wysocki and Sweet (1985) were able to classify correctly 84% of the patients overall and all tests in the battery discriminated between brain-damaged and normal subjects, with 11 of the 14 tests separating brain-damaged from schizophrenic patients. The authors recommended that cross-validation research with their battery was needed, especially with patients reflecting mild neurological dysfunction.

In summary, studies involving adults suggest the need for cross-validation research to bolster the validity of the batteries reviewed in particular and the use of abbreviated batteries in general. Different subject populations should also be administered one or more of the batteries to determine the efficacy of brief batteries across a broader range of potential subjects.

Children's Batteries. Tsushima and Towne (1977) initiated a study to discern whether neuropsychological test results could differentiate between children 6-8 years old with "questionable" brain disorders and normal controls. The authors also attempted
to determine which of the neuropsychological measures, via discriminant analysis, best differentiated between the groups, that is, they attempted to find the "best diagnostic battery" for use with "questionably" brain-damaged subjects. All BD subjects were experiencing learning problems in school. Results of the data analysis found 10 of the 37 variables separated the two groups statistically. Grip-Strength, Finger Tapping, Tactile Finger Recognition with the nondominant hand and the Picture Completion subtest of the WISC-R were found to be the best discriminators and were used to form their "best diagnostic battery." Administration of this "best" battery to the 62 subjects in the study (31 brain-damaged and 31 controls) yielded a correct classification rate of 72.6%. The full 37 measure battery was 85.5% correct in classifying the subjects. Tsushima and Towne stated that the discriminative power of their "compact" battery "compared favorably" with the accuracy of previous studies using a full battery of neuropsychological measures.

Reitan and Herring (1985) conducted the only published research with children to develop a "short screening device" based on the Halstead-Reitan Neuropsychological Test Battery for Children and Allied Procedures. Measures were chosen which had "short administration times, differentiated between groups at a high rate, evaluated overall level of performance, compared the
functioning of the two sides of the body, and identified pathognomonic signs" (p. 646).

Tests employed in the Reitan-Herring (1985) screening battery included some seen in the shortened adult batteries, some from the Tsushima and Towne (1977) study and other tests found useful by various researchers of children with brain related deficits (Boll, 1974; Klonoff & Low, 1974; Reitan, 1974; Rourke, 1985). Measures included were: The Trail Making Test (parts A and B); the entire Aphasia Screening Test; Name Writing (both hands); Grip Strength (both hands); and Finger Tapping (both hands).

Subjects in the Reitan and Herring (1985) study "were 50 brain-damaged (27 boys and 23 girls) and 50 neurologically normal (28 boys and 22 girls) children aged 9 through 14 years" (p. 644). Subjects in each group were assigned randomly to two groups having 25 subjects each. The first group was administered the complete Halstead-Reitan Neuropsychological Test Battery and Allied Procedures. Only those measures (12) which discriminated between the initial 25 brain-damaged and 25 normal subjects at the $p < .001$ level or better were considered for inclusion in the screening battery. Using those 12 measures, a discriminant function was developed which correctly classified 96% of the initial group. From the 12 measures, 8 were selected ultimately
for inclusion in the final screening battery. Using the 8 measures, application of the discriminant analysis to the initial group of 50 subjects resulted in a 94% correct classification rate; cross-validation with the second half (50) of the subjects provided only a 68% correct classification rate. As a result, certain measures in the screening battery were weighted differently than others, individual weighted percentage indices were developed, cut-off scores which maximally separated each group (controls from brain-damaged) were identified and, ultimately, the final screening index was developed. It correctly classified 92% of the initial 50 subjects and 86% of the validation group.

Reitan and Herring (1985) cautioned that the screening index was "not equivalent to a summary measure of deficit, such as the Halstead-Impairment Index for adults...[or] the Children's Impairment Index...Thus, in no sense should a screening index be viewed as an adequate exploration of brain-behavior relationships for children with cerebral disorders or normal brain functions" (p. 648). These researchers stated that their "purpose in developing the screening index was oriented explicitly toward achieving the best differentiation of brain-damaged and control subjects in as short a testing time as possible" (p. 648). They also called for cross-validation studies and assessment of the
usefulness of the screening battery in the evaluation "of children with other conditions that may or may not be brain-related, such as learning deficits" (p. 648).

In summary, studies employing a brief battery of neuropsychological screening tests which discriminate at a high level between normals and brain-damaged adults and children have shown diagnostic power. None of the researchers, however, intended their screening battery to replace a comprehensive neuropsychological assessment when deemed appropriate for the client. All of the investigators, including Reitan, agreed that since not every case warranted a complete neuropsychological evaluation, and yet information regarding the intactness of the clients' cerebral functioning was necessary, it was appropriate to use a quick, but well thought out, broad based, screening battery, with documented high levels of discriminative, diagnostic power.
**Method**

**Subjects**

Fifty-eight students, 29 learning disabled (LD) and 29 "average" controls (AC)—9 through 11 years of age—attending public school classes in eight elementary schools in Las Vegas, Nevada, constituted the total sample of subjects for this study. Forty subjects were males and 18 were females. Forty-eight subjects were caucasian and ten were nonwhites.

**Learning Disabled (LD).** Twenty-nine LD subjects met State and Federal (PL 94-142) Standards as Learning Disabled and were attending the Resource Room program at their neighborhood school. All LD subjects considered for inclusion in this study also had to meet strict statistical discrepancy criteria based on current regression formula, taking into consideration the reliability of the measures used and the correlation among them. Either the Full Scale IQ of the Wechsler Intelligence Scale for Children-Revised (WISC-R) or the Mental Processing Composite (MPC) Standard Score (SS) on the Kaufman Assessment Battery for Children (K-ABC) had to fall at or above a score of 80 to ensure that the LD students had intellectual abilities within the average range.

**Average Controls (AC).** Twenty-nine "average" control students were matched to the LD students by age (± six months),
sex, and grade in school (if possible). Whenever possible, the AC student was attending the same homeroom as his/her LD match. If this was not possible, a same sex and aged AC child was found, usually at the same school.

To be considered an "average" control, subjects also had to meet the following additional criteria:

1) Student was not currently receiving and/or had no history of receiving special education services, that is, learning disabled, emotionally disturbed, visually impaired, etc. The student was also not currently enrolled in a remedial reading program such as RIP or Chapter I.

2) Student was not currently being considered for, or being referred for, special education assessment.

3) Student had no history, as reported by the parent on the Medical History Questionnaire (see Appendix I), of any neurological disease or disorder.

4) Student had school district standardized test scores available for screening to assess his/her cognitive abilities. Otis-Lennon Scholastic Aptitude Test (OLSAT) IQ scores were required to be 80 or better.

**Procedures**

**Subject Selection.** Special education records were reviewed by the school psychologist to identify LD children meeting the
criteria of this study. Then a school psychologist identified another student in the LD child's homeroom that matched on the basis of age (± six months) and grade level. This was done by random selection from class lists and review of pertinent school records. If no suitable student could be found, then a matched AC was found in a different classroom at the same school and grade level if possible. Parents of the AC and LD children were contacted for permission to include their child in the research project and were asked to complete the Medical History Questionnaire (see Appendix 1) to rule out the possibility of neurological findings in the child's history. Included in the study were only those AC and LD students whose parents had a working telephone, agreed to have their child tested, and whose medical histories were within normal limits, i.e., did not show a history of hard neurological findings such as head trauma, perinatal asphyxia, encephalitis, seizure disorder, etc. If any criterion was not met, another suitable student was identified.

**Age.** Mean age differences between the LD and AC groups were considered. Analysis of variance (ANOVA) was conducted with the critical level set at \( p < .01 \) comparing the mean ages of the groups. No significant differences in mean age were found (\( p < .9 \)) between the LD (\( M = 124.45 \) months, \( SD = 10.31 \)) and AC groups (\( M = 124.59 \), \( SD = 9.61 \)).
IQ. Mean IQ differences between groups were compared using an ANOVA, with the critical value set at \( p < .01 \). Group IQ scores (OLSAT) were obtained from records of the AC subjects and WISC-R or K-ABC scores were used for LD subjects. No significant difference in IQ was found (\( p < .083 \)) between the LD (\( M = 100.28, SD = 11.41 \)) and AC groups (\( M = 105.55, SD = 11.66 \)).

Testing. Assessment was conducted during 1986-88. Testing was performed after school hours during the school week or on Saturdays for the AC students, either at the child’s school or at this writer’s private office. Testing of the LD students was conducted during regular school hours at their neighborhood school. All assessments were conducted by three school psychologists trained by a practicing clinical neuropsychologist and the present researcher (who was trained by the clinical neuropsychologist and at Dr. Reitan’s Basic Training Workshops). Tests in the screening battery were administered to both groups in a random order, (such as, to subject #1, NW, GS, FTT, ...; to subject #2, NW, TFR, AST, GS, ...). To establish hand dominance for the other tests in the battery, all subjects wrote their given and surnames at the beginning of the session.
Test Measures

The abbreviated battery from the HNTB-C for this study consisted of all of the measures from the Reitan and Herring (1985) study: Trail Making Test (Parts A and B); Finger Tapping Test; Aphasia Screening Test; Name Writing; and Grip Strength. In addition, the Tactile Finger Recognition and the Finger-Tip Number Writing tests were included from the Reitan-Klove Sensory-Perceptual Examination (Reitan, 1984).

For a complete description of the content, administration and scoring procedures of the individual measures used in this study, the reader is referred to appropriate manuals and texts (Reitan, 1974; Reitan, 1984; Reitan & Wolfson, 1985; Reitan, 1987). A brief description is included in Appendix 2.

Scoring

Tests in the abbreviated battery used in this study were scored according to methods set forth in manuals appropriate for the tests (Reitan, 1979, 1984, 1987), as well as in accordance with the guidelines set forth by Reitan and Herring (1985). Raw score means and standard deviations also were recorded for each group (LD, AC) at each age level. Items on the Aphasia Screening Battery were rated (per Reitan, 1987) by a clinical neuropsychologist to whom group membership of each subject was unknown.
Questions for Investigation

Five questions were posed for investigation in this study:

1) Can the Screening Index from the abbreviated HNIB-C discriminate between the LD and AC groups? 2) Are the AC students' scores in this study similar (Screening Index < .20; see Appendix 4) to the control subjects' scores in the Reitan and Herring (1985) study? 3) Are the LD students' scores in the present study less impaired than the brain-damaged subjects' scores in the Reitan and Herring (1985) study? and 4) Are the sensory-perceptual tests able to discriminate successfully between the LD and AC groups?
Hypotheses

The following hypotheses were posited for investigation in this study:

Hypothesis 1
The LD group will score significantly higher on their mean screening index score than will the AC group.

Hypothesis 2
The mean screening index score of the AC group in the present study will not be significantly different from the control group's mean in the Reitan and Herring (1985) study.

Hypothesis 3
The mean screening index score of the LD group in the present study will be significantly lower than the mean screening index score of the brain damage group in the Reitan and Herring (1985) study.

Hypothesis 4
For Total Errors on the Tactile Finger Recognition Test, the LD group will score significantly higher than the AC group on mean scores.

Hypothesis 5
For the Right-Left Error Difference on the Tactile Finger Recognition Test, the LD group will score significantly higher than the AC group on mean scores.
Hypothesis 6
For the Total Errors on the Finger-tip Number Writing Test, the LD group will have a significantly higher mean score than the AC group.

Hypothesis 7
For Right-Left Error Difference on the Finger-tip Number Writing Test, the LD group will have a significantly higher mean score than the AC group.

Hypothesis 8
For each of the tests in the abbreviated battery used in this study, there will be significant mean converted (Selz-Reitan Rules System, Selz & Reitan, 1979) score differences between the LD and AC groups, with the LD group scoring more impaired than the AC group.
Results

Appendix 4 contains raw score means, standard deviations and t-scores for all measures administered in this study for the LD and AC groups. Some of the measures were not directly analyzed as part of this study, but are included for comparison purposes.

Hypothesis 1

It was predicted that the LD group would receive a significantly higher Screening Index score than the AC group. Means and standard deviations are presented in Table One. The mean Screening Index score of the LD group (.23) was significantly higher than the AC group’s (.10), $t = 4.931$, $p < .0005$.

Table 1

Mean Screening Index Scores for the LD and AC Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>LD</td>
<td>.23</td>
<td>.11</td>
</tr>
<tr>
<td>AC</td>
<td>.10*</td>
<td>.08</td>
</tr>
</tbody>
</table>

* $p < .0005$

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Hypothesis 2

It was predicted that the mean Screening Index score of the AC group would not be significantly different from Reitan and Herring’s (1985) control group mean Screening Index score. The mean Screening Index scores of the two control groups were not significantly different, t = .387, p < .40. Means and standard deviations are presented in Table 2.

Table 2

Mean Screening Index Scores for the AC Group and the Control Group of Reitan & Herring (1985)

<table>
<thead>
<tr>
<th>Group</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC</td>
<td>.10</td>
<td>.08</td>
</tr>
<tr>
<td>Control</td>
<td>.11</td>
<td>.11</td>
</tr>
</tbody>
</table>

Hypothesis 3

It was predicted that the mean Screening Index score of the LD group in the present study would be significantly lower than the mean Screening Index score of the brain damaged group in the Reitan and Herring study (1985). The LD group scored
significantly lower in mean Screening Index Score (.23) than the BD group (.33) in the Reitan and Herring study (1985), $t = 2.51$, $p < .01$. Means and standard deviations are presented in Table 3.

Table 3
Mean Screening Index Scores for the LD Group and the BD Group of Reitan & Herring (1985)

<table>
<thead>
<tr>
<th>Group</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>LD</td>
<td>.23</td>
<td>.11</td>
</tr>
<tr>
<td>BD</td>
<td>.33*</td>
<td>.18</td>
</tr>
</tbody>
</table>

* $p < .01$

Hypothesis 4
It was predicted that, on mean scores, the LD group would score significantly more Total Errors on the Tactile Finger Recognition test than the AC group. The LD group (4.55) made significantly more Total Errors on the Tactile Finger Recognition test than did the AC group (2.48), $t = 2.65$, $p < .01$.

Table 4 presents the means, standard deviations, and $t$-scores for all of the tactile-perceptual tests administered in
this study. Scores for some of the tests not analyzed in this study are also included for comparison purposes. Table 4 contains data for discussions pertaining to Hypotheses 4-7.

Table 4
Raw Score Means, Standard Deviations, and t-tests for Tactile Perceptual Measures for the AC and LD Groups

<table>
<thead>
<tr>
<th>Measure</th>
<th>AC</th>
<th>LD</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFR - Total Errors</td>
<td>2.48 2.15</td>
<td>4.55 3.62</td>
<td>2.646**</td>
</tr>
<tr>
<td>TFR - R/L Difference</td>
<td>1.24 1.35</td>
<td>1.45 1.40</td>
<td>.571</td>
</tr>
<tr>
<td>TFR - R-Hand Errors</td>
<td>0.97 1.05</td>
<td>2.07 2.07</td>
<td>-2.56**</td>
</tr>
<tr>
<td>TFR - L-Hand Errors</td>
<td>1.52 1.66</td>
<td>2.48 2.06</td>
<td>-1.963*</td>
</tr>
<tr>
<td>FTWP - Total Errors</td>
<td>5.31 4.25</td>
<td>12.10 7.87</td>
<td>4.091****</td>
</tr>
<tr>
<td>FTWP - R/L Difference</td>
<td>1.93 1.65</td>
<td>2.72 1.87</td>
<td>1.715*</td>
</tr>
<tr>
<td>FTWP - R-Hand Errors</td>
<td>2.79 2.66</td>
<td>6.52 4.32</td>
<td>-3.949****</td>
</tr>
<tr>
<td>FTWP - L-Hand Errors</td>
<td>2.52 2.28</td>
<td>5.59 4.17</td>
<td>-3.478***</td>
</tr>
</tbody>
</table>

*p < .05; **p < .01; ***p < .005; ****p < .0005
Hypothesis 5

It was predicted that, on mean scores, the LD group would make significantly more errors for Right-Left Error Difference on the Tactile Finger Recognition test than the AC group. On mean scores, the LD (1.45) and AC (1.26) groups did not significantly differ on Right-Left Error Difference on the Tactile Finger Recognition test, $t = .571$, $p < .30$. Means and standard deviations are presented in Table 4.

Hypothesis 6

It was predicted that the LD group would make significantly more mean errors than the AC group for Total Errors on the Finger-tip Number Writing test. On mean scores, the LD group (12.1) made significantly more Total Errors on the Finger-Tip Number Writing test than did the AC group (5.3), $t = 4.091$, $p < .0005$. Means and standard deviations are presented in Table 4.

Hypothesis 7

It was predicted that, on mean scores, the LD group would score significantly higher than the AC group for Left-Right Error Difference scores on the Finger-tip Number Writing test. The LD group (2.72) scored significantly more mean errors on Left-Right Error Differences than did the AC group (1.93), $t = 1.715$, $p < .05$. Means and standard deviations are presented in Table 4.
Table 5

Converted Score Means, Standard Deviations, and t-tests for the
Seven Screening Battery and Four Tactile-Perceptual Measures for
the AC and LD Groups

<table>
<thead>
<tr>
<th>Measure</th>
<th>AC</th>
<th>SD</th>
<th>LD</th>
<th>SD</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td>TMT - Part A</td>
<td>.207</td>
<td>.412</td>
<td>.552</td>
<td>.631</td>
<td>-2.46**</td>
</tr>
<tr>
<td>TMT - Part B</td>
<td>.207</td>
<td>.412</td>
<td>.828</td>
<td>.889</td>
<td>-3.41***</td>
</tr>
<tr>
<td>NW - R/L Difference</td>
<td>.310</td>
<td>.712</td>
<td>.552</td>
<td>.828</td>
<td>1.191*</td>
</tr>
<tr>
<td>NW - Preferred Hand</td>
<td>.379</td>
<td>.622</td>
<td>.517</td>
<td>.634</td>
<td>.837</td>
</tr>
<tr>
<td>FTT - Nonpreferred Hand</td>
<td>.069</td>
<td>.371</td>
<td>.076</td>
<td>.409</td>
<td>.336</td>
</tr>
<tr>
<td>FTT - R/L Difference</td>
<td>.552</td>
<td>.572</td>
<td>.379</td>
<td>.562</td>
<td>1.158</td>
</tr>
<tr>
<td>GS - R/L Difference</td>
<td>.207</td>
<td>.620</td>
<td>.276</td>
<td>.528</td>
<td>.456</td>
</tr>
<tr>
<td>TFR - R/L Difference</td>
<td>.483</td>
<td>.911</td>
<td>.621</td>
<td>.979</td>
<td>.555</td>
</tr>
<tr>
<td>TFR - Total Errors</td>
<td>.414</td>
<td>.623</td>
<td>1.035</td>
<td>1.017</td>
<td>-2.797***</td>
</tr>
<tr>
<td>FTTWP - R/L Difference</td>
<td>.379</td>
<td>.677</td>
<td>.828</td>
<td>1.003</td>
<td>-1.996*</td>
</tr>
<tr>
<td>FTTWP - Total Errors</td>
<td>.379</td>
<td>.903</td>
<td>1.586</td>
<td>1.240</td>
<td>-4.238****</td>
</tr>
</tbody>
</table>

* p < .05; ** p < .01; *** p < .005; **** p < .0005

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Hypothesis 8

Hypothesis Eight investigated the differences on mean converted scores between the LD and AC groups for each of the tests in the abbreviated battery used in this study: Trails A, Trails B, Finger Tapping Test, Strength of Grip, Name Writing. The LD group was predicted to evidence more impairment on each of the tests than the AC group.

Table Five summarizes the converted score means, standard deviations, and _t_ - scores of all of the screening battery and tactile-perceptual measures. On the Trail Making Test, Part A, the LD group scored significantly more impaired on mean converted scores than did the AC group, _t_ = 2.46, _p_ < .01.

On the Trail Making Test, Part B, the LD group scored significantly more impaired on mean converted scores than did the AC group, _t_ = 3.41, _p_ < .005.

For the Right-Left Difference score on the Name Writing test, the LD group scored significantly higher on mean scores than the AC group, _t_ = 2.191, _p_ < .05.

No significant differences between the LD and AC groups were found on mean converted scores for the nonpreferred hand on the Finger Tapping Test, for Right-Left Difference speed of the Finger Tapping Test, for Right-Left Difference strength on the Strength of Grip test, for preferred hand speed on the Name Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.
Writing test, and for Right-Left Error Difference score on the Tactile Finger Recognition test. Means, standard deviations, and \( t \) - scores are summarized in Table 5.

Post Hoc analysis was conducted on the converted score means, standard deviations, and \( t \) - scores for the tactile-perceptual measures for the AC and LD groups. They are summarized in Table 5. For Total Errors on the Tactile Finger Recognition test, the LD group made significantly more total errors in localizing fingers touched than did the AC group, \( t = 2.80, p < .005 \).

For the Right-Left Error Difference score of the Finger-tip Number Writing test, the LD group made significantly more errors in number writing recognition when errors between the left and right hands were compared, \( t = 2.00, p < .05 \).

For the Total Error score on the Finger-tip Number Writing test, the LD group made significantly more Total Errors in recognizing numbers written on their finger-tips than did the AC group, \( t = 4.238, p < .0005 \).
Discussion

Screening Index Results

Reitan and Herring (1985) developed a "short screening battery" that was able to discriminate 9-14 year old students with previously diagnosed brain damage from average students of the same age. Results of the present study support the use of the screening battery with 9-11 year olds in discriminating average from learning-disabled students who are suspected (Hammill et al, 1981) of having central nervous system dysfunction.

The LD students in the present study received a mean Screening Index score (.23) twice as large as the controls in both the present study and Reitan and Herring (1985) study. In addition, control subjects in the present study and those in the Reitan and Herring (1985) study earned essentially equivalent mean Screening Index scores, .10 and .11, respectively. Only three average controls in the present study (10%) scored at or above the mean score for the LDs, or above the cutoff score (.20) suggested by Reitan and Herring (1985) to discriminate best between their control and brain damaged subjects. Using .20 as the cut-off score for the Screening Index, 76% of the subjects were classified correctly—90% of the ACs and 62% of the LDs.
Table 6 summarizes raw score cut-offs and resulting classification accuracies for the screening battery and tactile-perceptual measures.

Table 6

<table>
<thead>
<tr>
<th>Measure</th>
<th>Cut-Off Score</th>
<th>Classification Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>AC</td>
</tr>
<tr>
<td>Aphasia Screening Test (Pathognomonic total)</td>
<td>7</td>
<td>100%</td>
</tr>
<tr>
<td>Screening Index</td>
<td>.20</td>
<td>90%</td>
</tr>
<tr>
<td>TMT - Part B</td>
<td>43&quot;</td>
<td>90%</td>
</tr>
<tr>
<td>FTWP - R-Hand</td>
<td>6+ errors</td>
<td>90%</td>
</tr>
<tr>
<td>FTWP - Total Errors</td>
<td>11+ errors</td>
<td>86%</td>
</tr>
<tr>
<td>FTWP - L-Hand</td>
<td>4+ errors</td>
<td>79%</td>
</tr>
<tr>
<td>FTT - Nonpreferred Hand</td>
<td>36+ taps</td>
<td>86%</td>
</tr>
<tr>
<td>TMT - Part A</td>
<td>16&quot;</td>
<td>79%</td>
</tr>
<tr>
<td>TFR - Total Errors</td>
<td>6+ errors</td>
<td>93%</td>
</tr>
<tr>
<td>TFR - R-Hand</td>
<td>2+ errors</td>
<td>72%</td>
</tr>
<tr>
<td>TFR - L-Hand</td>
<td>3+ errors</td>
<td>69%</td>
</tr>
</tbody>
</table>
Results of the present study are also similar to those of Reitan and Wolfson (1988) and Selz and Reitan (1979) who found that 9-14 year old learning disabled students earned higher mean impairment scores (.23) than control subjects (.10), but lower impairment scores than children with diagnosed brain damage (.33). The present study found, as did the Selz and Reitan (1979) study, that LD students were more likely to earn lower impairment scores, i.e., scores more similar to control than brain damaged subjects, if a misclassification error were made. Table 7 summarizes raw score mean, standard deviation, impairment cut-offs, and t-test significance levels for the screening battery and tactile-perceptual measures for the AC and LD groups.
<table>
<thead>
<tr>
<th>Measure</th>
<th>Raw Score Mean (SD)</th>
<th>Converted Score Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trail Making Test -</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LD</td>
<td>16.93 (5.37)</td>
<td>.55 (.63)</td>
</tr>
<tr>
<td>AC</td>
<td>12.90 (3.53)**</td>
<td>.21 (.41)**</td>
</tr>
<tr>
<td>Part B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LD</td>
<td>43.38 (15.48)</td>
<td>.83 (.89)</td>
</tr>
<tr>
<td>AC</td>
<td>31.59 (9.52)**</td>
<td>.21 (.41)**</td>
</tr>
<tr>
<td><strong>Finger Tapping Test</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonpreferred Hand</td>
<td>(26 or less = impaired)</td>
<td>(2.3 = impaired)</td>
</tr>
<tr>
<td>LD</td>
<td>36.44 (4.72)</td>
<td>.10 (.41)</td>
</tr>
<tr>
<td>AC</td>
<td>39.87 (5.39)</td>
<td>.07 (.37)</td>
</tr>
<tr>
<td>Right/Left Difference (-.16 or less = impaired)</td>
<td>(2.3 = impaired)</td>
<td></td>
</tr>
<tr>
<td>LD</td>
<td>.08 (.07)</td>
<td>.37 (.56)</td>
</tr>
<tr>
<td>AC</td>
<td>.06 (.12)</td>
<td>.55 (.57)</td>
</tr>
<tr>
<td><strong>Grip Strength</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right/Left Difference (-.07 or less = impaired)</td>
<td>(2.3 = impaired)</td>
<td></td>
</tr>
<tr>
<td>LD</td>
<td>.07 (.08)</td>
<td>.28 (.63)</td>
</tr>
<tr>
<td>AC</td>
<td>.08 (.09)</td>
<td>.21 (.62)</td>
</tr>
<tr>
<td><strong>Name Writing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Hand</td>
<td>(25&quot; = impaired)</td>
<td>(2.3 = impaired)</td>
</tr>
<tr>
<td>LD</td>
<td>15.38 (7.10)</td>
<td>.52 (.62)</td>
</tr>
<tr>
<td>AC</td>
<td>13.76 (8.22)</td>
<td>.38 (.62)</td>
</tr>
<tr>
<td>Right/Left Difference (25&quot; = impaired)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LD</td>
<td>17.07 (8.25)</td>
<td>.55 (.83)</td>
</tr>
<tr>
<td>AC</td>
<td>15.55 (8.44)</td>
<td>.31 (.71)*</td>
</tr>
<tr>
<td><strong>Tactile Finger Recognition</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Errors</td>
<td>(4 = impaired)</td>
<td>(2.3 = impaired)</td>
</tr>
<tr>
<td>LD</td>
<td>4.55 (1.62)</td>
<td>1.03 (1.02)</td>
</tr>
<tr>
<td>AC</td>
<td>2.48 (2.15)**</td>
<td>.41 (.065)**</td>
</tr>
<tr>
<td>Right/Left Difference (4 = impaired)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LD</td>
<td>1.45 (1.40)</td>
<td>.62 (.90)</td>
</tr>
<tr>
<td>AC</td>
<td>1.24 (1.25)</td>
<td>.48 (.91)</td>
</tr>
<tr>
<td><strong>Finger-tip Number Writing</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perception-Total Errors</td>
<td>(8+ = impaired)</td>
<td>(2.3 = impaired)</td>
</tr>
<tr>
<td>LD</td>
<td>12.10 (7.87)</td>
<td>1.59 (1.24)</td>
</tr>
<tr>
<td>AC</td>
<td>5.31 (4.25)****</td>
<td>.38 (.90)****</td>
</tr>
<tr>
<td>Perception-Right/Left Difference</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LD</td>
<td>2.72 (1.47)</td>
<td>.83 (1.00)</td>
</tr>
<tr>
<td>AC</td>
<td>1.93 (1.65)*</td>
<td>.38 (.68)*</td>
</tr>
</tbody>
</table>

*p < .05; **p < .01; ***p < .005; ****p < .0005
**Tactile-Perceptual Results**

Inclusion of tactile perceptual measures in a screening battery for children with learning disabilities seems highly warranted, given the results of the present study. All but one statistical comparison of tactile measures between the LD and AC groups was significant, both for raw and converted score mean data. Only the Right-Left Difference score for the Tactile Finger Recognition test did not reach significance. The Right-Left Difference score for the Finger-tip Number Writing test was the second weakest (p < .05) predictor of the tactile measures, suggesting that right-left comparisons on tactile perceptual measures may be less salient diagnostically for LD students, at least for those in this study, than level of performance comparisons.

More specifically, Finger-tip Number Writing measures in this study provided greater differentiation between groups (p < .05 - .0005) than did those from Tactile Finger Recognition measures (p < .05 - .01). For the tactile tests, Right Hand and Total Error scores provided the best separation between the LD and AC groups (see Table 6). The Total Error and Right Hand error scores on Finger-tip Number Writing were the most discriminating tactile perceptual diagnostic scores obtained (p < .0005). On this test the LD group made over twice as many Total errors.
Errors ($X = 12.1$) as did the AC group ($X = 5.3$).

The findings in the present study add further support to previous research findings suggesting that poor readers are more likely than average readers to have tactile imperception (Boll, Berent & Richards, 1977; Boll & Reitan, 1972; Boll, Richards, & Berent, 1978; Del Dotto & Rourke, 1985; Finlayson & Reitan, 1976; Gaddes, 1985; Joschko & Rourke, 1985; Reed, 1967; Reitan, 1984; Rourke, 1985). The findings also suggest that both of the tactile perceptual measures used in this study should become part of the school psychologist's diagnostic battery for learning disability diagnosis.

**Converted Score Results of Individual Test Measures**

Raw scores for the individual tests in the present study, excluding tactile perceptual measures, were changed to converted scores via procedures from Reitan and Herring (1985) to determine the Screening Index. Analysis of $t$-test comparisons of the LD and AC groups for the individual tests used in the present study revealed only three of seven significant differences between the groups. While converted score means for Right-Left Difference on the Name Writing test were significantly different for the LD and AC groups, $p < .05$, raw score means were not significantly different, $t = .693, p < .24$ (see Table 7). In addition, only 6 of the 29 LD students (21%), in comparison to 2 of 29 AC students...
(7%), had converted scores in the impaired range (scores of 2 or 3).

Greater separation between the LD and AC groups was achieved on both parts of the Trail Making, the only other test to show significant converted score differences between the two groups. Using both converted and raw score means, the two groups differed significantly from each other (see Table 7). However considering converted scores, only 2 of 29 LDs (7%) on Part A and 7 of 29 LDs (24%) on Part B scored within the impaired range. These results suggest that for an individual child referred for diagnosis of possible learning disabilities, low Trail Making test converted score impairment levels may mislead a diagnostician into believing the child is not learning disabled when, in fact, s/he may be. These results also suggest that when including the use of the Trail Making test in LD diagnosis, impairment level cut off scores may need to be readjusted to times closer to the LD's mean times in the present study (Part A, 17 seconds; Part B, 43 seconds).

**Sampling Comparisons to Previous Studies**

Raw score data from the present study were compared to previous studies including LD students to determine similarities between the samples of LD students evaluated. On Screening Index scores alone, the AC group in the present study and the controls
in the Reitan and Herring (1985) study were not significantly different. Similarly on the Trail Making Test, the AC subjects in the present study obtained mean times for both Parts A and B (13 seconds and 32 seconds, respectively) similar to the control subjects in the Selz and Reitan (1979) study (15 seconds and 36 seconds, respectively). However, the LD subjects in the present study were faster than LD subjects in either the Selz and Reitan (1979) or Fischer et al. (1986) studies, suggesting possible sampling differences between the LD subjects in the present study and those in previous studies which reported mean score data. Therefore, conclusions based on the present data need cross validation, or must be noted to reflect sampling variance, thus limiting generalizability. Means and standard deviations are summarized in Tables 8 and 9.
Table 8
Mean Part A Trail Making Test Scores for LD Subjects in Three Different Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Webb</td>
<td>16.93</td>
<td>5.37</td>
</tr>
<tr>
<td>Selz &amp; Reitan (1979)</td>
<td>24.28</td>
<td>10.91</td>
</tr>
<tr>
<td>Fischer et al. (1986)</td>
<td>21.39</td>
<td>11.74</td>
</tr>
</tbody>
</table>

aChildren were 9-14 years old

Table 9
Mean Part B Trail Making Test Scores for LD Subjects in Three Different Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Webb</td>
<td>43.38</td>
<td>15.49</td>
</tr>
<tr>
<td>Selz &amp; Reitan (1979)</td>
<td>63.12</td>
<td>53.08</td>
</tr>
<tr>
<td>Fischer et al. (1986)</td>
<td>60.86</td>
<td>44.93</td>
</tr>
</tbody>
</table>
Differences were also found on the Finger Tapping Test where the LD subjects in the present study were faster tappers than the LD subjects in the Selz and Reitan (1979) and Fischer et al. (1986) studies. Means and standard deviations are summarized in Tables 10 and 11.

Table 10
Mean Dominant Hand Scores on the Finger Tapping Test for LD Subjects in Three Different Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Webb</td>
<td>39.68</td>
<td>5.36</td>
</tr>
<tr>
<td>Selz &amp; Reitan (1979)</td>
<td>35.88</td>
<td>4.43</td>
</tr>
<tr>
<td>Fischer et al. (1986)</td>
<td>30.98</td>
<td>5.73</td>
</tr>
</tbody>
</table>
Table 11

Mean Nondominant Hand Scores on the Finger Tapping Test for LD Subjects in Three Different Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Webb</td>
<td>36.44</td>
<td>4.72</td>
</tr>
<tr>
<td>Selz &amp; Reitan (1979)</td>
<td>32.60</td>
<td>5.74</td>
</tr>
<tr>
<td>Fischer et al. (1986)</td>
<td>28.76</td>
<td>4.77</td>
</tr>
</tbody>
</table>

These comparisons suggest that the LD subjects in the present study may have been less impaired by their learning disability on these two measures—TMT, FTT—than the subjects in the previous studies.

Best Discriminating Measures of the Study

Using the Reitan and Herring (1985) screening battery and including the tactile perceptual measures from the present study, a psychologist attempting to evaluate a 9-11 year old child for possible learning disabilities can have even more confidence in his/her diagnosis by including the total screening battery evaluated in the present study and by scrutinizing the subject's scores on the following most discriminating measures of the present study: Aphasia Screening Test Total, Screening Index...
score, Total Errors on the Tactile Finger Recognition test, Total Errors on the Finger-tip Number Writing test, Right Hand Errors on the Finger-tip Number Writing test, and Part B of the Trail Making Test.

The greatest degree of separation between the groups in this study was achieved by using the total score (of pathognomonic signs) of the Aphasia Screening Test (AST). Inspection of the data in Table 6 suggested that if a total score of seven is chosen as the cut off score to separate the groups, all AC subjects (100%) scored below this level and 90% of the LDs scored at or above it, a classification rate of 95% for all subjects. Similarly, on mean scores there was a significant difference between the two groups ( \( t = 9.208, p < .0005 \)) with the mean for the LD group (10.52 ± 4.50) over three times greater than the mean for the AC group (2.97 ± 1.72). These findings support those of Selz and Reitan (1979) and Wolfson and Reitan (1988) in using the AST with LDs.

As stated above, only three AC subjects in the present study (10%) scored at or above .20 on their Screening Index score, while 66% of the LDs did, a 76% classification rate. Results of the present study support the .20 cut off score for discriminating control subjects from those children suspected of having varying degrees of cerebral dysfunction.
For Part B of the Trail Making Test, no AC subject earned a converted score within the impaired range (2 or 3), whereas 24% of the LDs did. Hence, when a child's Part B time on the TMT falls within the impaired range on converted scores, the child should be suspected of a possible learning disability or some other cerebral dysfunction. In addition, only 17% (5 of 29) of the AC group obtained Part B times equal to or longer than 40 seconds, versus 55% (16 of 29) of the LDs, a 75% classification rate—90% for ACs and 62% for LDs. The discriminating power of the TMT in the present study supports previous research using the TMT with LDs (Del Dotto & Rourke, 1985; Joschko & Rourke, 1985; McManis et al., 1978; Rourke & Finlayson, 1975).

For Total Errors on the Tactile Finger Recognition test only two AC subjects (7%) made more than five total errors, whereas 31% of the LD subjects (9 of 29) made six or more errors, a 62% classification rate—93% for ACs and 31% for LDs. Performance at this level on converted scores falls within the impaired range and suggests that children with total error rates at or above six on TFR are more likely to be a LD than control subject. These data support Selz and Reitan's (1979) finding that even children who function normally in school display some tactile imperception in comparison to adults.
For Total Errors on the Finger-tip Number Writing test, 11 errors or greater appeared to separate the groups maximally. Only 14% (4 of 29) of the controls, but 59% of the LDs, made that many imperception errors and performance at or above this level on converted scores falls within the impaired range, a 71% classification rate—86% for ACs and 59% for LDs.

For Right Hand Errors on the Finger-tip Number Writing test six or more errors appeared to separate the groups maximally. Only 10% (3 of 29) of the AC group made six or more errors with their right hand versus 59% (17 of 29) of the LDs, a 74% classification rate—86% for ACs and 59% for LDs.

Limitations of the Study

Sample sizes in the present study could have been larger and drawn on a more random basis. More low income and minority families could have been encouraged to participate in this study. These variables limit the generalizability of the results of the study, in particular to low income minorities.

In addition, the full age span—9 to 14—was not included to fully covalidate Reitan and Herring's study and to allow for age comparisons.

While the highest level of clinical practice was used in administering the items in the battery, group membership was known to all examiners at the time of testing and examiner bias
or drift may have influenced the resulting test scores.

**Future Research Recommendations**

Larger samples of control and LD students should be evaluated, especially using the tactile perceptual measures, to develop normative data for future subject comparisons for diagnostic purposes. Age comparison should also be assessed.

This study, as well as the full age range from Reitan and Herring's (1985) screening battery, should be covalidated to further support the diagnostic usefulness of the screening battery developed in this study for LD screening and/or inclusion as part of the battery for LD evaluations.

Further research on the diagnostic discriminative power of the Aphasia Screening Test and the Tactile-Perceptual measures used in this study would appear highly useful.

Discriminative analysis should be performed on the data in this study to determine, statistically, the optimal cut-off levels to discriminate between the LD and AC groups. As part of such a study, the weightings of the individual measures should be reevaluated to determine if, for the LD subjects, in comparison to the brain damaged subjects in Reitan and Herring's (1985) study, different weightings are more discriminative for LD versus control comparisons.
References


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Appendix I

Medical History Questionnaire

I. IDENTIFYING INFORMATION

_________________________   ___________________   ___________________
Name of Student   Birthdate   Grade

II. HISTORY OF PREGNANCY

Did the mother experience any accidents, trauma, or serious
illnesses during this pregnancy?    If so, please explain.

Was medicine taken by the mother during this pregnancy?    If yes,
what and for how long?

X-rays?    Did mother use beer, wine, alcoholic beverages during
pregnancy?    If yes, how much?

III. BIRTH HISTORY

What did the baby weigh at birth?

Was delivery premature?    If yes, by how many weeks?

Were there any problems during labor?    If yes, please explain.

Did the baby present head first?

Were forceps used?

Was a Caesarean section done?    If yes, were you told why?
Was there any birth injury? _____ If yes, please explain. __________

__________________________________________________________

__________________________________________________________

IV. HISTORY OF NEWBORN

This section refers to the baby's time in the hospital at birth.

Did baby cry without assistance at birth? _____

Did the baby have trouble breathing? _____ Eating? _____

Any other health problems? _____ If yes, please explain. __________

__________________________________________________________

Did the baby go home with mother? _____ If no, how many days was the baby hospitalized? _____ Why? _____________________________________________

V. DEVELOPMENTAL HISTORY

How old was the baby when s/he: Walked alone? _____ Said first words? _____ First sentences? _____

Do you feel the baby developed or grew normally? If no, please explain. _________________________________________________

__________________________________________________________

VI. ILLNESS, MEDICATION AND ACCIDENT HISTORY

Did this child ever have a high fever? _____ If yes, how high and for how long? ____________________________
Did this cause convulsions? __ If yes, was child placed on any medicine? __

Please explain that problem and any serious accidents, injuries, or illness.

Did/does your child have any of these health problems?

Seizures, Convulsions ______ Head Injuries ______
Meningitis ______ Dizziness ______
Encephalitis ______ Unconsciousness ______
Physical Disability ______ Frequent Ear Infections ______
Learning or behavior problems in school ______
Vision Problems ______
Hearing Problems ______

List any other health problem or physical disabilities. __________

Does your child take any medicine? __ If yes, what kind? ______

How much? __________

When? __________ Why? __________

Comments on any of the above? __________

I, __________________________ agree/do not agree to my child's participation in the study.

(parent signature) (circle one)
Appendix 2

Dependent Measures

Trail Making Test

This test (Reitan, 1974) is composed of two parts, A and B. Part A is administered first, followed by Part B. Each is composed of one 8 1/2 x 11 sheet of paper with a demonstration section on the front and the actual test on the back.

In Part A, the child is required, under time pressure, to draw a line connecting the circled numbers 1 through 15 in sequence. The numbers are randomly arranged on the page and the subject's score is recorded as the number of seconds required to finish, as well as the number of errors.

In Part B, scoring is the same, e.g., total time and number of errors. The subject's task is to draw the line, as rapidly as possible, connecting numbers (1-8) and letters (A-G). S/he must start at 1, go to A, then 2, then B, etc., alternating between numbers and letters until reaching number 8.

Administration time is less than five minutes.

"It seems likely that the ability to deal with the numerical and language symbols (numbers and letters) is sustained by the left cerebral hemisphere, the visual scanning task necessary to perceive the spatial distribution of the stimulus material is represented by
the right cerebral hemisphere, and speed and efficiency of performance may be a general characteristic of adequate brain functions. Thus, it is not surprising that this test is one of the best measures of general brain functions" (Reitan, 1955f; Reitan, 1958).

Name Writing

Without being informed, the subject is timed, initially in writing first and last name with the dominant hand and then the nondominant hand. Time taken for each hand is recorded and the difference in writing speed between the two hands is calculated.

Administration time is less than five minutes. This test measures motor speed of each hand involving practiced language symbols and has lateralizing value (Reitan, 1984; Reitan & Herring, 1985).

Grip Strength

Using a Smedley Hand Dynamometer, the subject first squeezes as hard as possible with the dominant hand and then with the nondominant hand. Each hand is tested a second time in the same order. Recordings are made of each trial and scores are averaged for each hand. The average kilograms between the two hands' scores are calculated for computing the screening index.

Administration time is less than five minutes. This test measures upper extremity motor strength and has lateralizing
value (Reitan, 1985; Reitan & Wolfson, 1985).

**Finger Oscillation (Tapping) Test**

This test measures fine motor speed and control. Using a specially designed tapping lever mounted to a counter, the subject is required to tap with the index finger as rapidly as possible for ten seconds, first with the dominant hand. Four additional ten-second trials are administered, with rest breaks where needed. Then, using the nondominant hand, the procedure is repeated for five trials. Scores are reported for each hand as the average number of taps over the five trials. The difference in tapping speed between hands is calculated for computing the screening index. This test has lateralizing value (Reitan & Wolfson, 1985).

**Reitan-Indiana Aphasia Screening Test**

The subject is asked to copy pictured objects, name pictured objects, spell the name of pictured objects, identify letters and numbers, read words and sentences, repeat words of increasing complexity, compute arithmetic calculations on paper and mentally without the use of paper and pencil, repeat a sentence, explain it and write it, demonstrate the use of an object, identify body parts, and display knowledge of left and right on self. Items are scored either pass/fail, with each failure indicative of a specific disorder (dyslexia, dyscalculia, dysnomia, etc.) and
given a predetermined weighted score.

This test measures primary language (enunciation, naming, comprehension and verbal expression) and secondary language (reading, spelling, writing, calculating) skills, body localization, left-right orientation on self, and demonstrating use of an object, all considered reflective of dominant hemisphere abilities. In addition, nondominant hemisphere abilities are considered measured by the drawing items (Reitan, 1984; Reitan & Wolfson, 1985).

**Tactile Finger Recognition (Finger Agnosia)**

The subject is instructed first that each finger is labeled one (thumb) through five (pinky), with a brief practice session in identifying which finger is touched. The test is begun using the right hand. With eyes closed, the subject's fingers are touched in a random order (no adjacent fingers are touched consecutively) and s/he is required to name the finger touched until each finger has been touched and named four times. Then the left hand is tested similarly. The score is the number of errors for the right hand and for the left hand.

This test measures tactile spatial perception and has lateralizing value (Reitan, 1984; Reitan & Wolfson, 1985).
Finger-tip Number Writing Perception

The subject is told that a number (3, 4, 5, 6) will be written on his/her finger-tip and s/he is to identify what number was drawn on the tip of the finger. With the subject's eyes closed and beginning with the thumb on the right hand, the numbers are written in a predetermined, random order. Each finger-tip on the right hand is tested and then the same procedure is employed with the left hand—thumb through pinky finger. The score is the number of errors on each individual hand.

This test is more difficult than Tactile Finger Localization, and also reflects tactile perceptual difficulties for symbolic material. This test has lateralizing value (Reitan, 1984; Reitan & Wolfson, 1985).
Appendix 3

Details of the Procedure for Scoring the Children's Screening Index

(Determine the column in which each score falls and multiply by the factor on the right (e.g., Trail A score of 13 = 0 x 7 = entry of 0). When dysphasic deficits are present, total the points and multiply by 1. Total the eight entries on the right and divide by 103.5.

<table>
<thead>
<tr>
<th>Trails A</th>
<th>15&quot; or less</th>
<th>16-25&quot;</th>
<th>26-35&quot;</th>
<th>36&quot;+</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trails B</td>
<td>36&quot; or less</td>
<td>40-55&quot;</td>
<td>56-70&quot;</td>
<td>71&quot;+</td>
<td></td>
</tr>
<tr>
<td>Tapping, non-preferred hand</td>
<td>30+</td>
<td>27-29</td>
<td>23-26</td>
<td>22 or less</td>
<td>1</td>
</tr>
<tr>
<td>Tapping, r-l difference</td>
<td>24-16</td>
<td>21-13</td>
<td>17-10</td>
<td>7-1</td>
<td>1</td>
</tr>
<tr>
<td>Grip Strength r-l difference</td>
<td>10-20</td>
<td>7-10</td>
<td>4-7</td>
<td>0-0</td>
<td>1</td>
</tr>
<tr>
<td>Name writing, preferred hand</td>
<td>10-8</td>
<td>8+</td>
<td>6-2</td>
<td>2 or less</td>
<td>1</td>
</tr>
<tr>
<td>Name writing, r-l difference</td>
<td>4+</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

Aphasia Battery:

- Constructional Dyspraxia
- Auditory Verbal Dysgnosia
- Visual Number Dysgnosia
- Visual Letter Dysgnosia
- Spelling Dyspraxia
- Central Dysarthria
- Dysnomia
- Dysgraphia
- Dyslexia
- Dyscalculia
- Right-left Confusion
- Body Dysgnosia

Total Screening Index = (Total/103.5)

3 Score equals 1 = (non-preferred hand - preferred hand)

*Use the following table to evaluate name writing performance:

<table>
<thead>
<tr>
<th>Time</th>
<th>Score</th>
<th>Time</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-9&quot;</td>
<td>10</td>
<td>Preferred slower</td>
<td>2</td>
</tr>
<tr>
<td>10-16&quot;</td>
<td>9</td>
<td>0-4&quot;</td>
<td>4</td>
</tr>
<tr>
<td>15-19&quot;</td>
<td>6</td>
<td>5-9&quot;</td>
<td>10</td>
</tr>
<tr>
<td>20-26&quot;</td>
<td>4</td>
<td>10-14&quot;</td>
<td>8</td>
</tr>
<tr>
<td>25-50&quot;</td>
<td>2</td>
<td>15-19&quot;</td>
<td>6</td>
</tr>
<tr>
<td>50&quot;+</td>
<td>0</td>
<td>20-14&quot;</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25-44&quot;</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>45&quot;+</td>
<td>1</td>
</tr>
</tbody>
</table>

### Appendix 4

**Raw Score Means, Standard Deviations and t-tests for All Measures**

Administered in the Study for the AC and LD Groups

<table>
<thead>
<tr>
<th>Measure</th>
<th>AC</th>
<th>SD</th>
<th>LD</th>
<th>SD</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trail Making Test</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Part B</td>
<td>31.59</td>
<td>9.52</td>
<td>43.38</td>
<td>15.48</td>
<td>-3.496***</td>
</tr>
<tr>
<td><strong>Finger Tapping Test</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Hand</td>
<td>42.46</td>
<td>5.18</td>
<td>39.68</td>
<td>5.36</td>
<td>2.004*</td>
</tr>
<tr>
<td>Nonpreferred Hand</td>
<td>39.87</td>
<td>5.39</td>
<td>36.44</td>
<td>4.72</td>
<td>2.578**</td>
</tr>
<tr>
<td>R/L Difference</td>
<td>.06</td>
<td>.16</td>
<td>.08</td>
<td>.07</td>
<td>-.787</td>
</tr>
<tr>
<td><strong>Grip Strength</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Hand</td>
<td>19.74</td>
<td>3.85</td>
<td>18.82</td>
<td>4.24</td>
<td>.869</td>
</tr>
<tr>
<td>Nonpreferred Hand</td>
<td>18.16</td>
<td>3.69</td>
<td>17.48</td>
<td>3.97</td>
<td>.678</td>
</tr>
<tr>
<td>R/L Difference</td>
<td>-.08</td>
<td>.09</td>
<td>.07</td>
<td>.08</td>
<td>.936</td>
</tr>
<tr>
<td><strong>Name Writing</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Hand</td>
<td>13.76</td>
<td>6.22</td>
<td>15.38</td>
<td>7.10</td>
<td>-.803</td>
</tr>
<tr>
<td>Nonpreferred Hand</td>
<td>28.48</td>
<td>13.83</td>
<td>33.28</td>
<td>11.22</td>
<td>-1.449</td>
</tr>
<tr>
<td>R/L Difference</td>
<td>-.08</td>
<td>.09</td>
<td>.07</td>
<td>.08</td>
<td>.936</td>
</tr>
<tr>
<td><strong>Tactile Finger Recognition</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Hand</td>
<td>.97</td>
<td>1.05</td>
<td>1.07</td>
<td>2.07</td>
<td>-2.56**</td>
</tr>
<tr>
<td>Left Hand</td>
<td>1.52</td>
<td>1.06</td>
<td>1.48</td>
<td>2.06</td>
<td>-1.963*</td>
</tr>
<tr>
<td>R/L Difference</td>
<td>1.24</td>
<td>1.35</td>
<td>1.45</td>
<td>1.40</td>
<td>-571</td>
</tr>
<tr>
<td>Total Errors</td>
<td>2.48</td>
<td>2.15</td>
<td>4.55</td>
<td>3.62</td>
<td>-2.646**</td>
</tr>
<tr>
<td><strong>Finger-tip Number Writing Perception</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right Hand</td>
<td>2.79</td>
<td>2.66</td>
<td>4.52</td>
<td>4.32</td>
<td>-3.949****</td>
</tr>
<tr>
<td>Left Hand</td>
<td>2.52</td>
<td>2.28</td>
<td>5.99</td>
<td>4.17</td>
<td>-3.478***</td>
</tr>
<tr>
<td>R/L Difference</td>
<td>1.93</td>
<td>1.65</td>
<td>3.72</td>
<td>1.87</td>
<td>-1.715*</td>
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<tr>
<td>Total Errors</td>
<td>5.31</td>
<td>4.25</td>
<td>11.10</td>
<td>7.87</td>
<td>-4.091****</td>
</tr>
<tr>
<td><strong>Screening Index</strong></td>
<td>.10</td>
<td>.08</td>
<td>.23</td>
<td>.11</td>
<td>-4.931****</td>
</tr>
<tr>
<td><strong>Aphasia Screening Test</strong></td>
<td>2.97</td>
<td>1.74</td>
<td>10.52</td>
<td>4.06</td>
<td>-9.208****</td>
</tr>
</tbody>
</table>

(Pathognomonic)

*p < .05; **p < .01; ***p < .005; ****p < .0005

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